Visual Data Mining Techniques and Software for Functional Actigraphy Data

Jürgen Symanzik & Abbass Sharif
Department of Mathematics and Statistics
Utah State University
e–mail: symanzik@math.usu.edu

Outline

What is Actigraphy?

- **Actigraphy:** emerging technology for measuring a person's activity level continuously over time
- **Actigraph:** watch-like device (attached to the wrist or leg) that uses an accelerometer to measure (human) movements (every minute or more often)

Actigraph

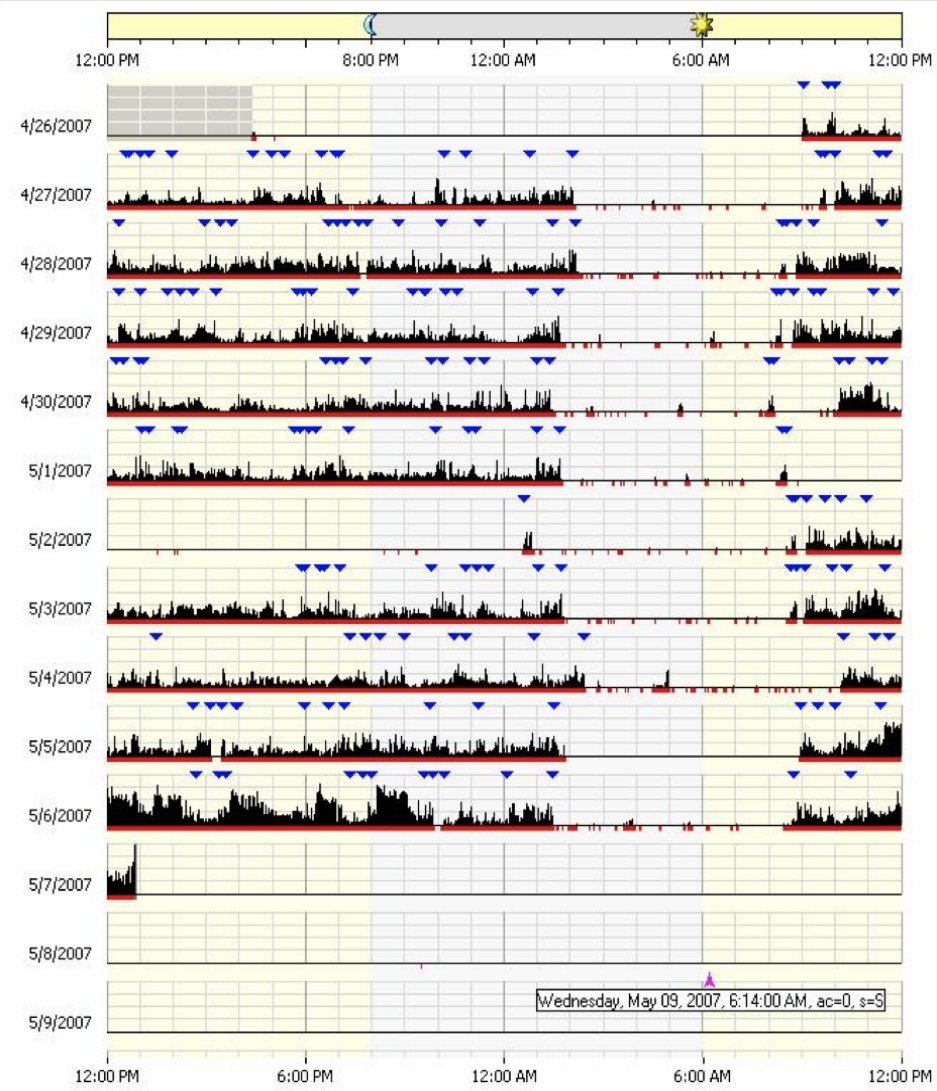

Respiratory
Accessibility
Rehab
Bi-Level
Bronchodilators
DME

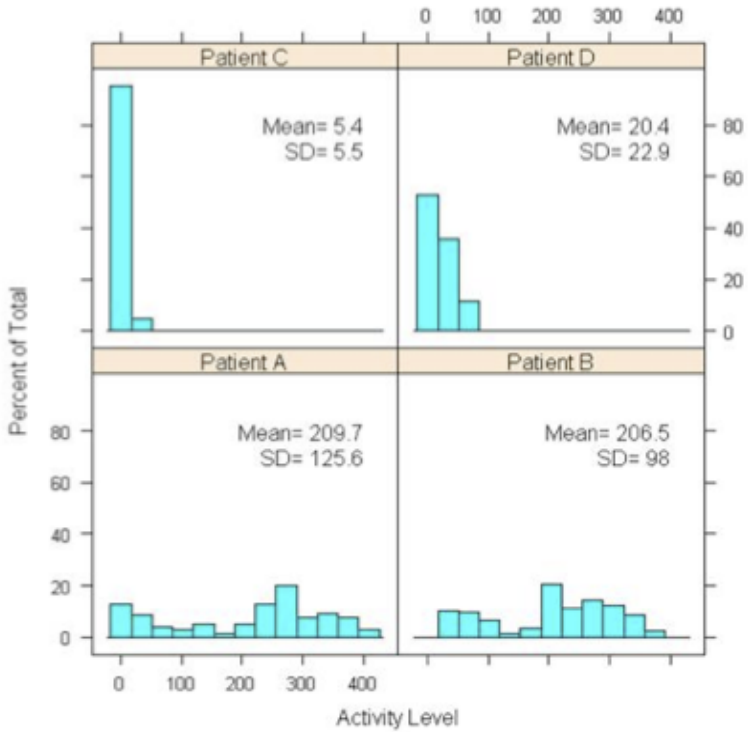

BH SCREENING RLS
DELL

Human Actigraphy

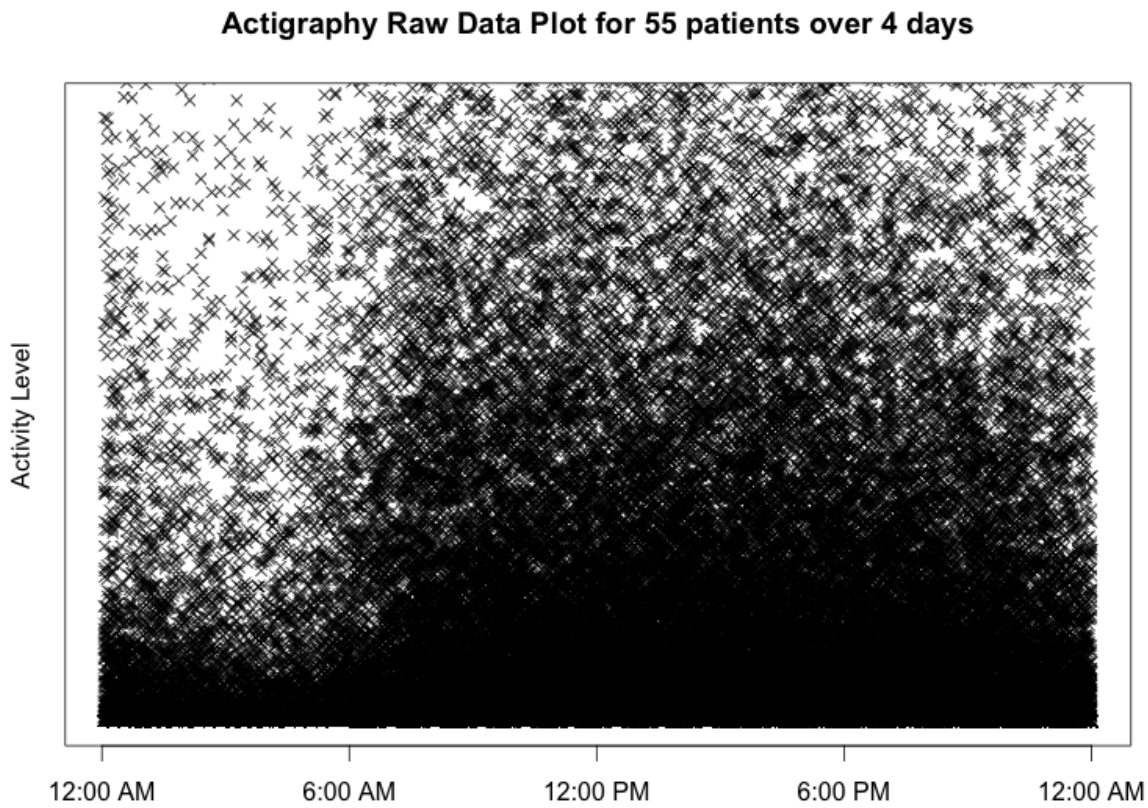
- Detecting sleep patterns, and insomnia
- Assessing restless leg syndrome
- Tracking recovery after heart attacks
- Assessing overall status of HIV patients
- Assessing depression
- Etc.

Current Visualizations of Actigraphy Data: Actogram & Histogram





Current Visualizations of Actigraphy Data: Scatterplot (Messy!)



Functional Data Analysis for Actigraphy Data

- Actigraphy data can be best described as functional data
- **Functional Data Analysis (FDA):** “The basic philosophy of functional data analysis is to think of observed data functions as single entities, rather than merely as a sequence of individual observations." (Ramsay & Silverman, 2006)

The ActiVis R Package

Feature 1:

New Visualization Tools for Actigraphy Data

Feature 2:

Integration of New and Current Visualization Tools Using Object–oriented Model Design

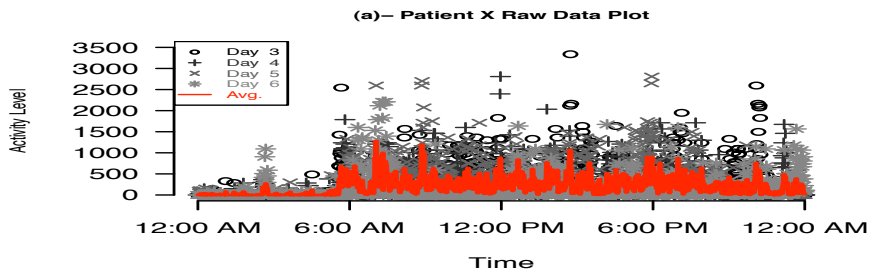
Feature 3:

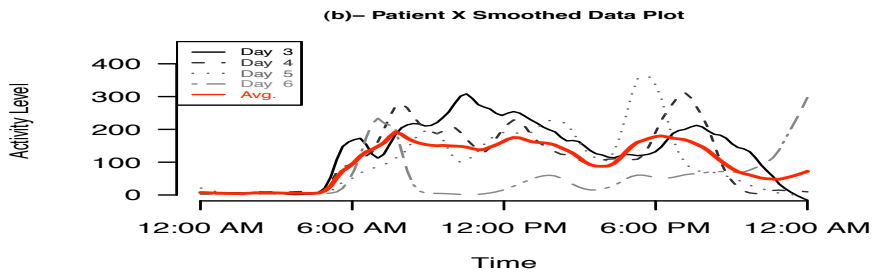
User–friendly Web Interface

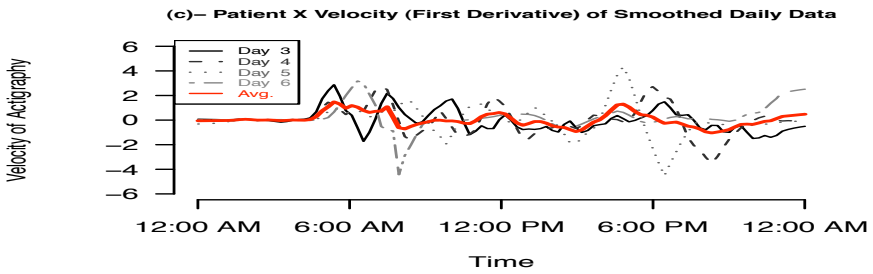
Feature 1: New Visualization Tools for Actigraphy Data

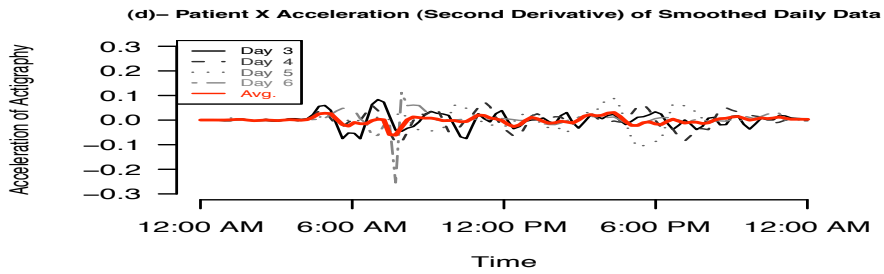
- One Patient
- Multiple Patients

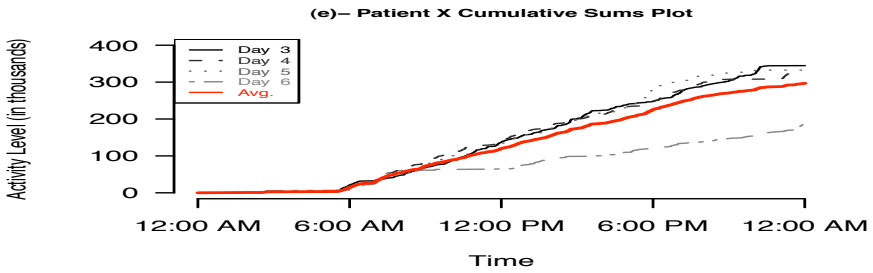
Enhanced Visualizations of Actigraphy Data: One Patient

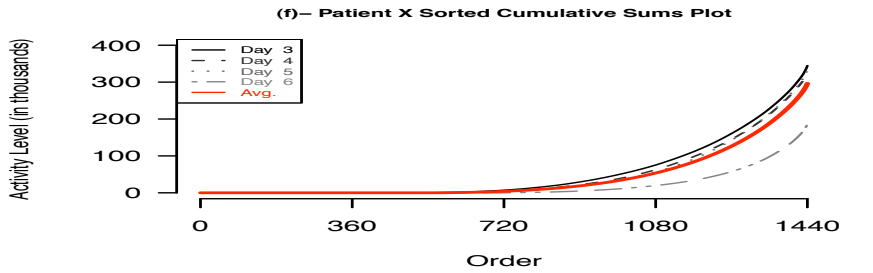












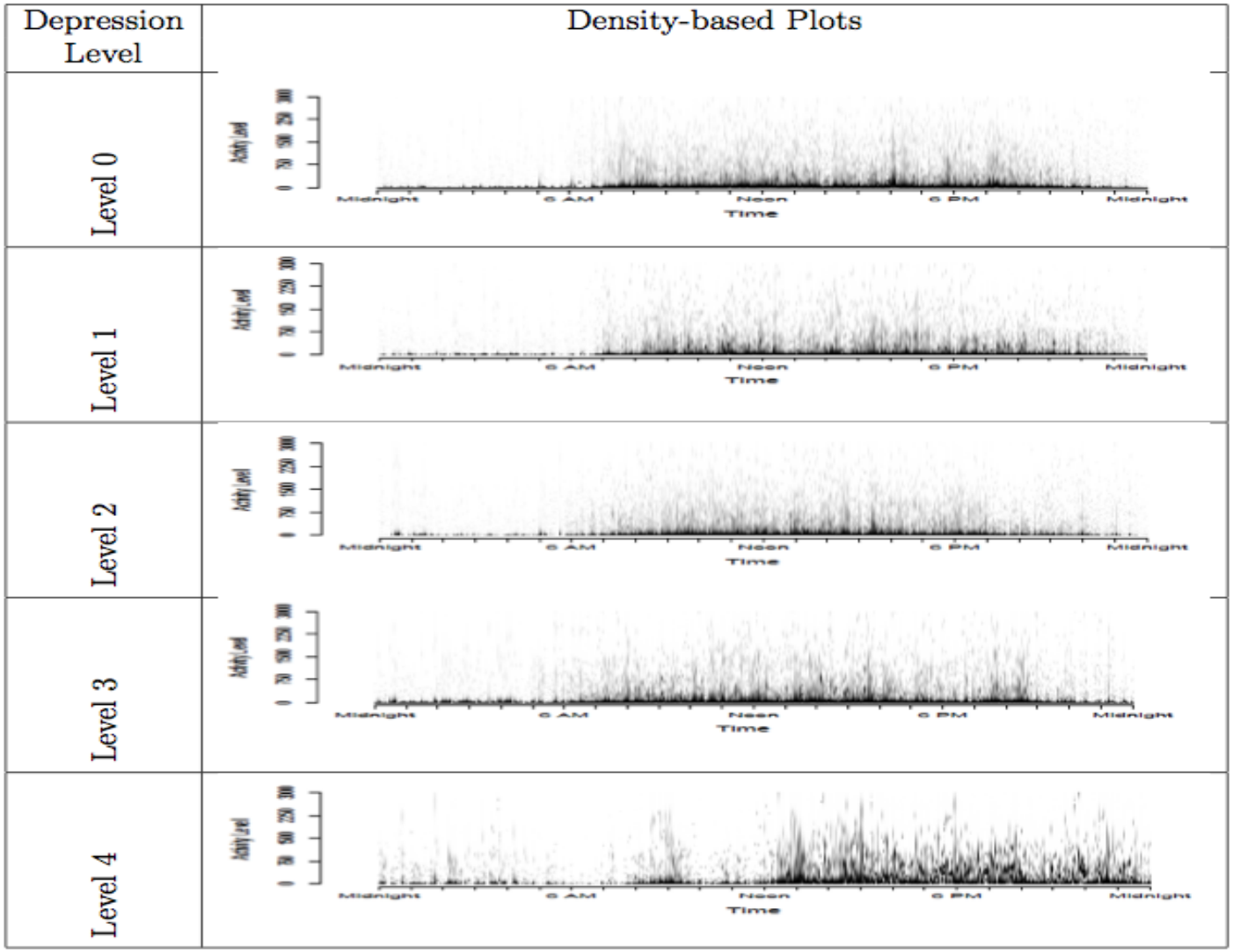
New Visualization Techniques for Actigraphy Data: Multiple Patients

- Density–based plots
- Data enveloping
- Data summing
- Multivariate time series plots
- Combination of plots (most effective)

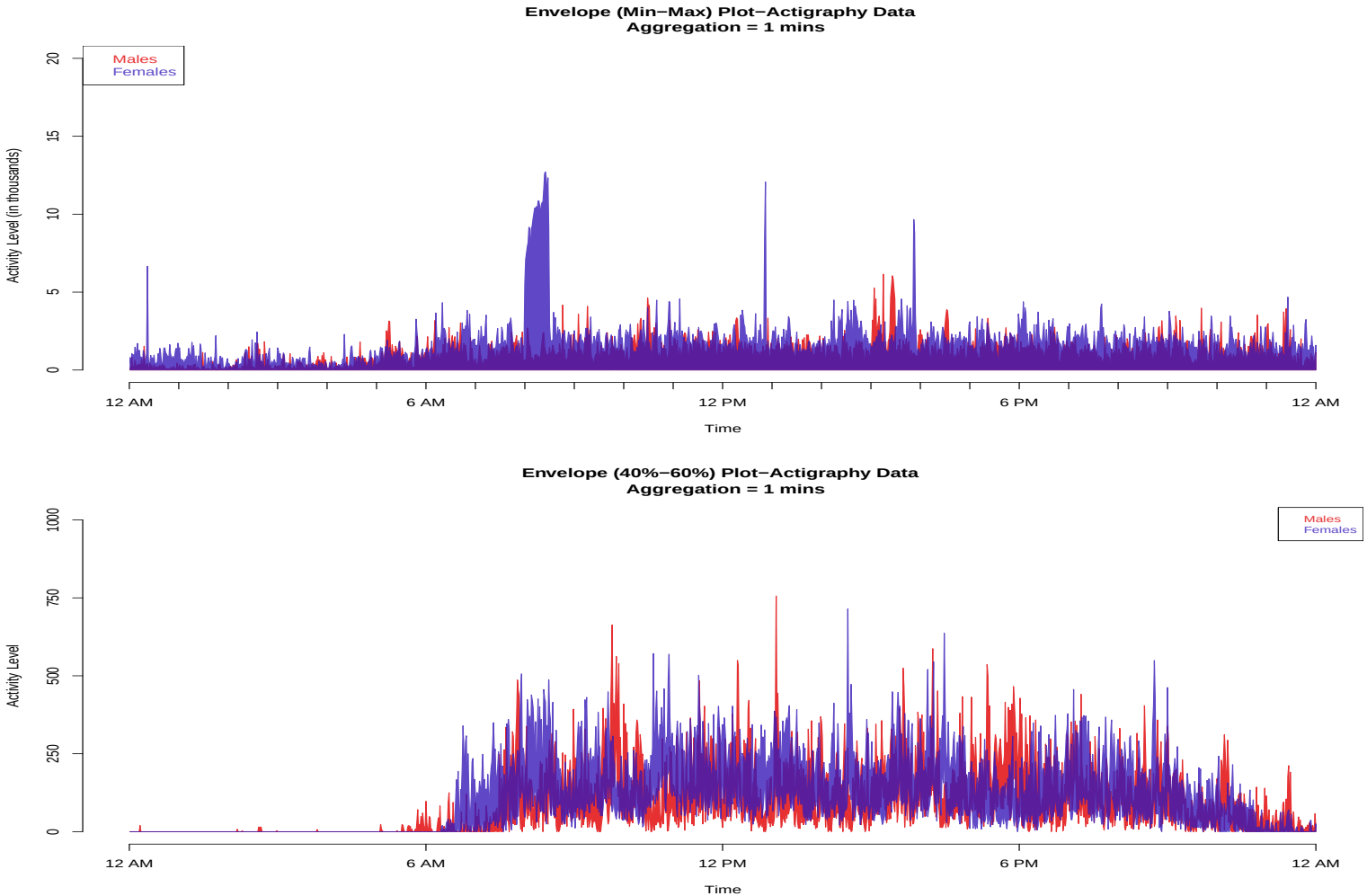
Actigraphy Data

- 55 patients
- Two types of data
  - Actigraphy level data
  - Depression level data (PHQ–9 scale)
- Data collection rate: every 15 seconds or every minute, i.e., about 6,000 or 1,500 measurements per day ($\times$ 3–8 days per patient $\times$ 55 patients)
- Patient demographics
  - Gender: 17 males, and 38 females
  - Depression level: 15 patients with no depression (Level 0), 13 with mild depression (Level 1), 15 with moderate depression (Level 2), 8 with moderately severe depression (Level 3), and 4 with severe depression (Level 4)

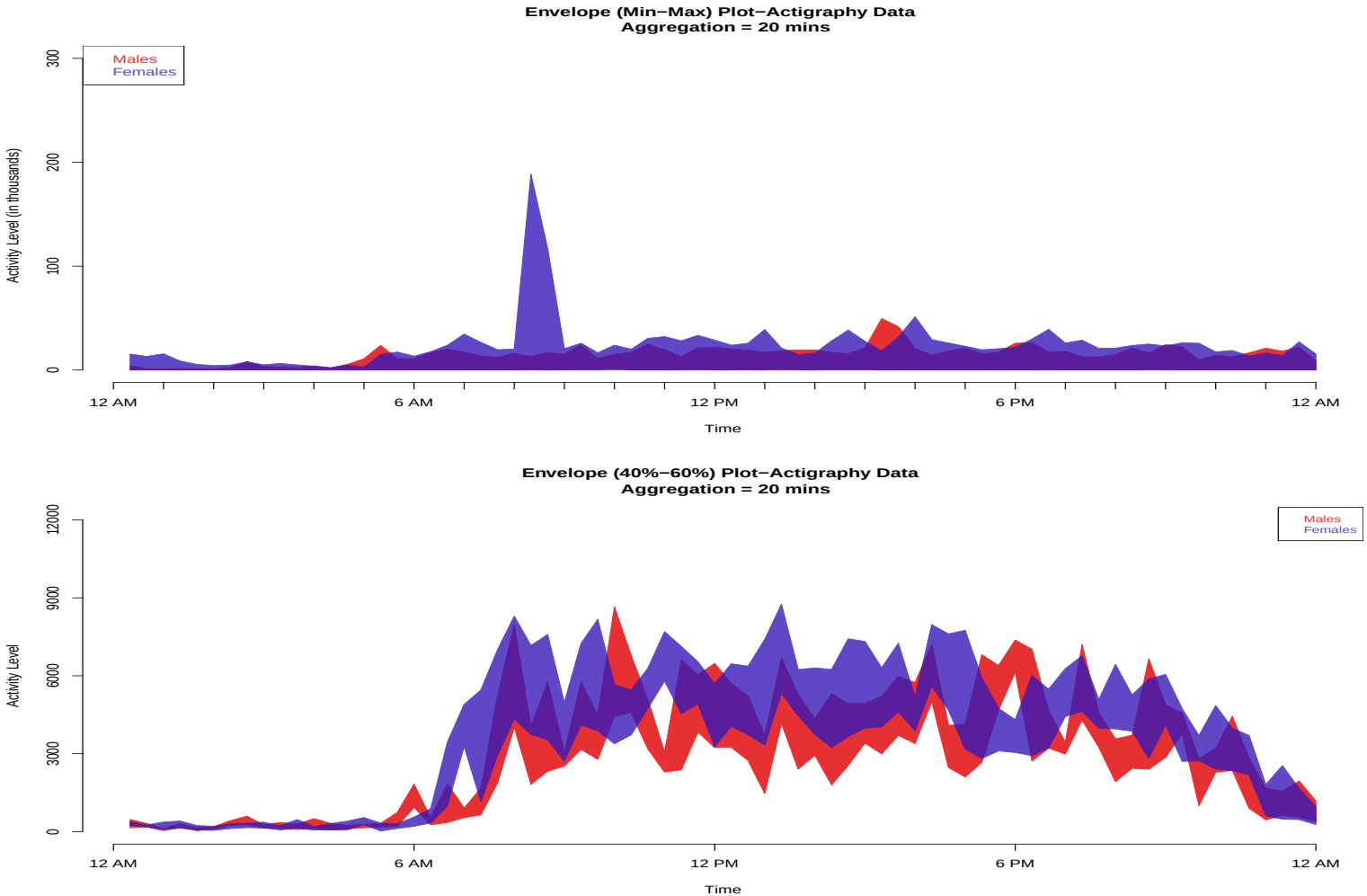
Density–based Plots: Multiple Patients



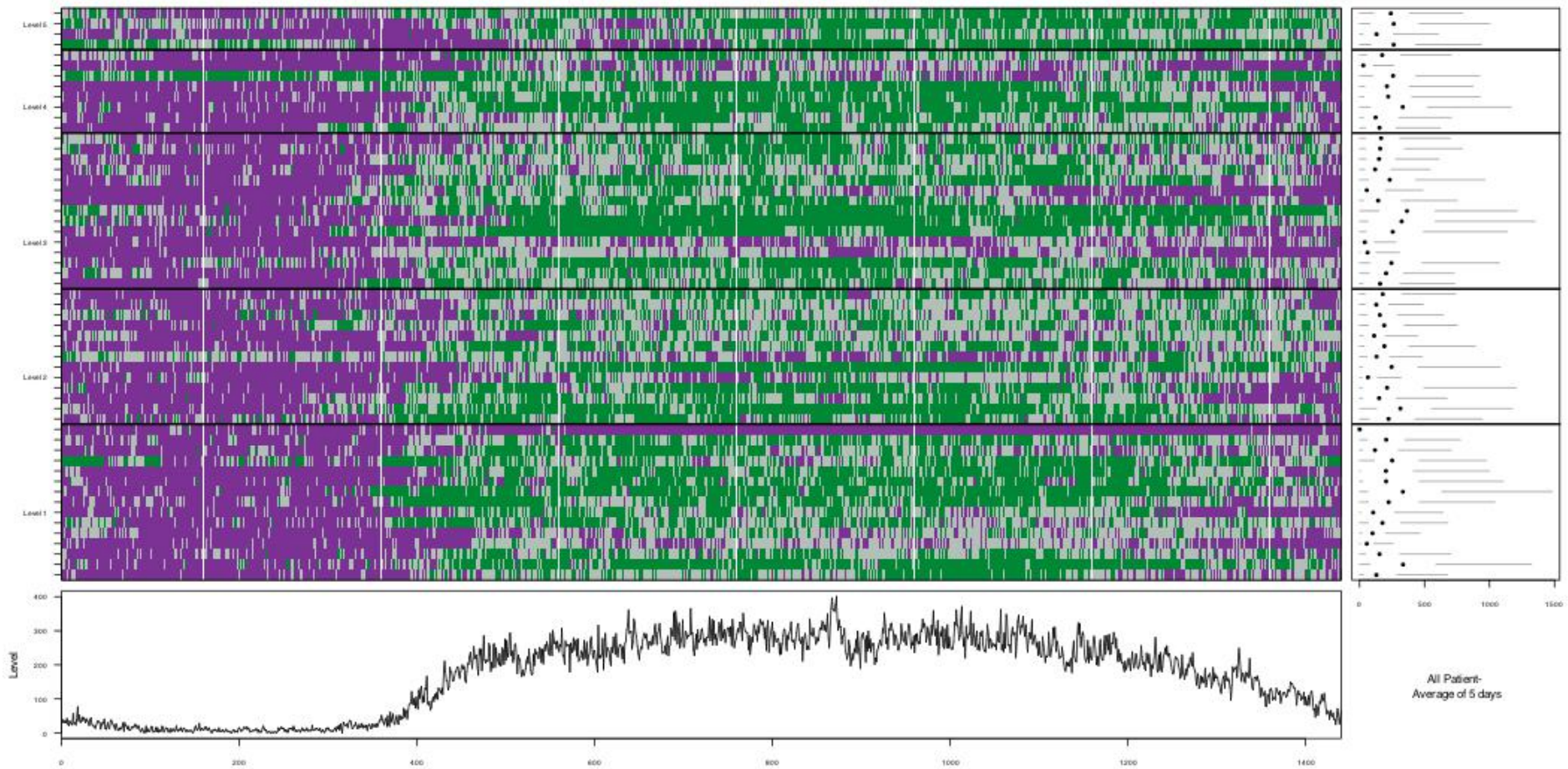
Data Enveloping: Multiple Patients



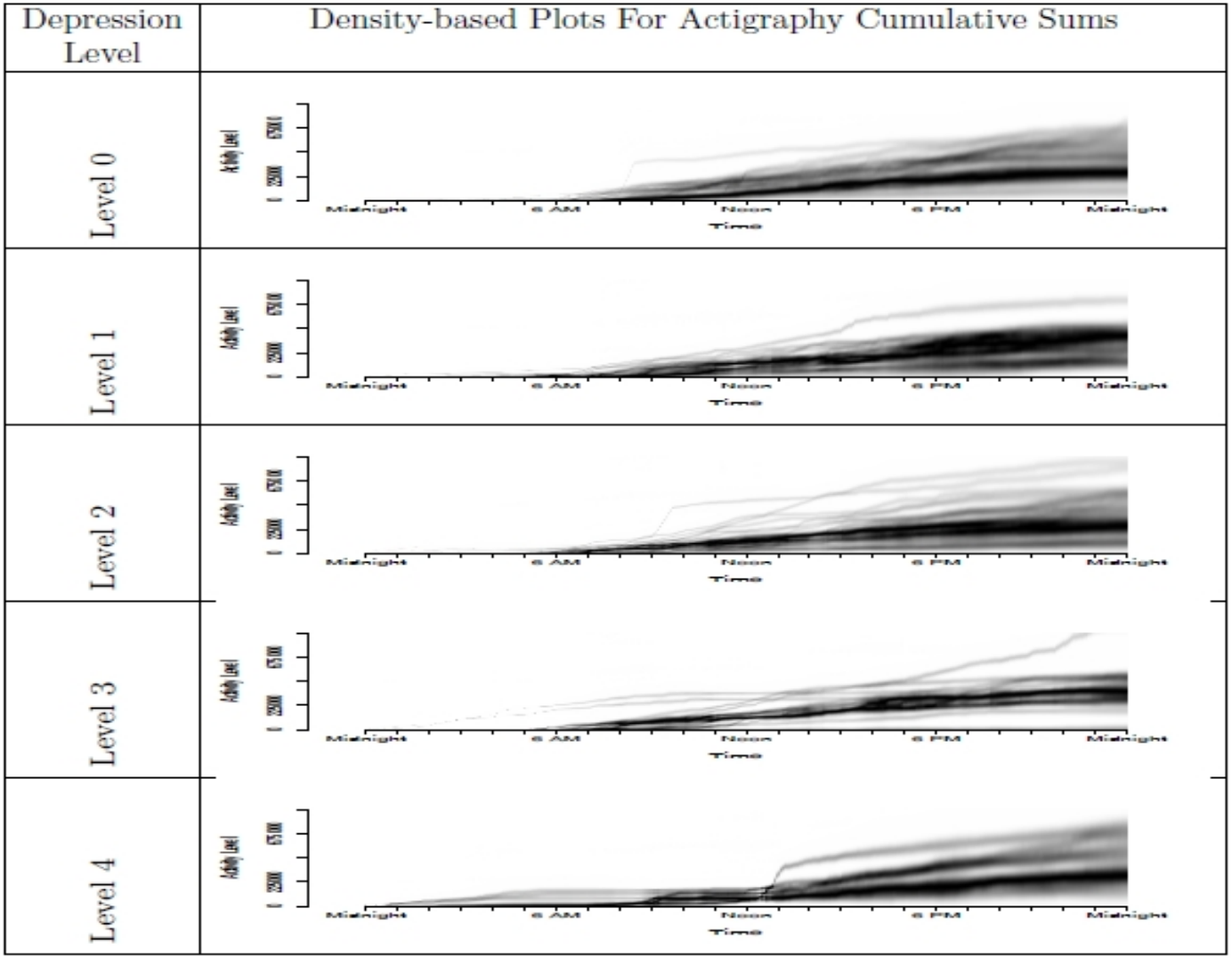
Data Summing: Multiple Patients



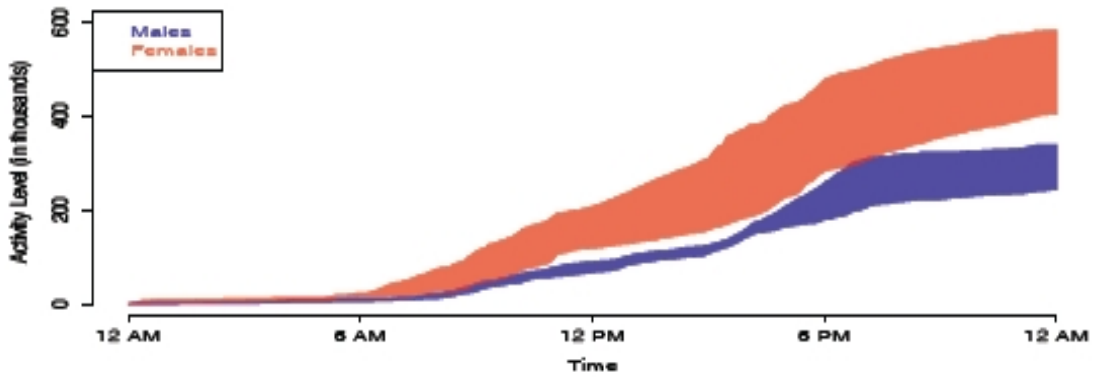
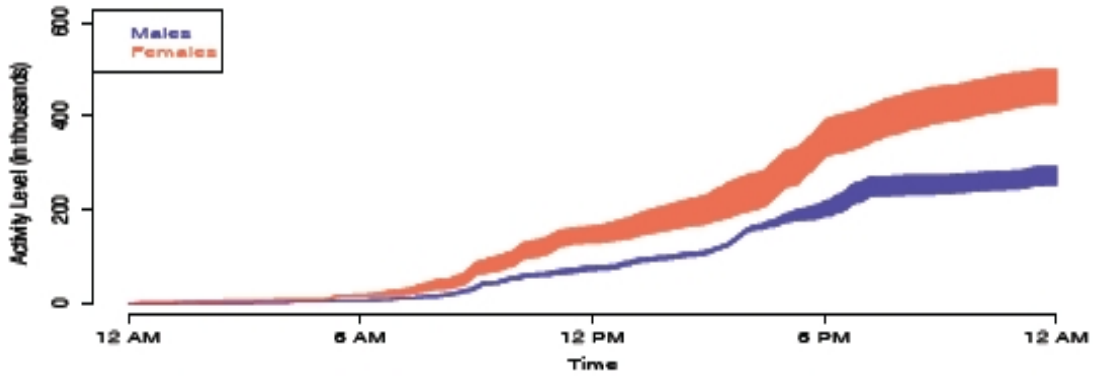
Multivariate Time Series Plots: Multiple Patients



Density–based Plots of Cumulative Sums: Multiple Patients



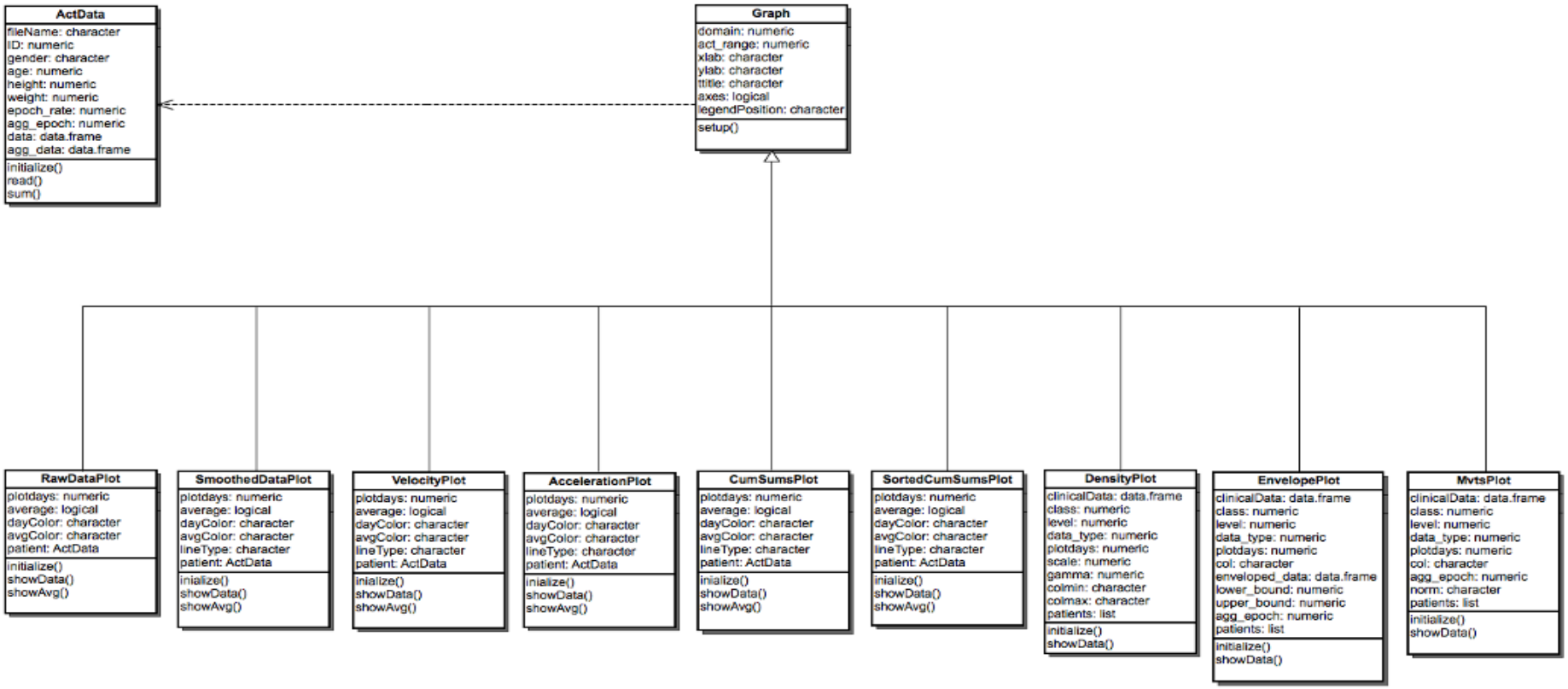
Envelope Plots of Cumulative Sums: Multiple Patients

Percentile	Data Envelopes for Actigraphy Data (Patient's Gender Categories)
$25^{th} - 75^{th}$	
$40^{th} - 60^{th}$	

What is Object–oriented Programming (OOP)?

- Objects: encapsulate state information and control behavior
- Classes: describe general properties for groups of objects
- Inheritance: new classes can be defined in terms of existing classes
- Polymorphism: a function/method has different behaviors depending on the class of one or more of its arguments

ActiVis Class Diagram



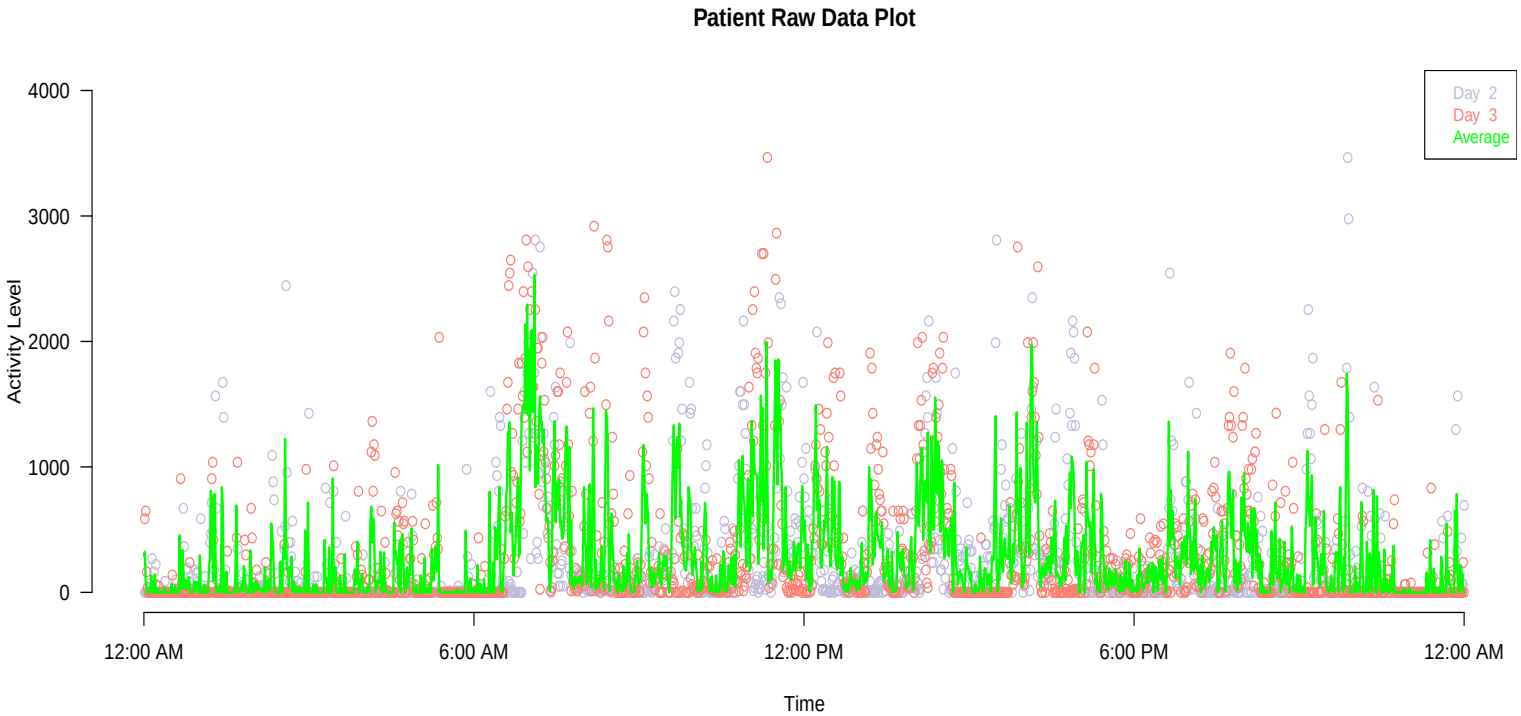
Object–oriented Programming in R

- S3 System
  - Easiest to use
  - Not fully object–oriented
- S4 System
  - Fully object–oriented
  - Less computationally efficient when compared to the S3 system
- R.oo Package
  - Extends the S3 system
  - Easy to use, and more user friendly
  - Makes use of reference variables
- R5 System
  - Reference Classes
  - Similar to R.oo, but it is part of R
  - We decided to use the R5 approach

Case Study: Single Patient R Code

```
library(ActiVis)
### inialize actigraphy object for this  patient
patient <- ActData$new()
patient$fileName <- "Patient.AWC"
### read the data
patient$read()
### create a new raw data plot object for this patient
patient_raw <- RawDataPlot$new()
patient_raw$legendPosition <- "topright"
patient_raw$act_range <- c(0, 4000)
### setup the graph by calling the graphics device
patient_raw$setup()
### show the average of data for the days
patient_raw$average <- TRUE
### what days to plot?
patient_raw$plotdays <- c(2, 3)
### store this patient's object in "patient" field in the graph object
patient_raw$patient <- patient
### show the data on the raw data plot
patient_raw$showData()
```

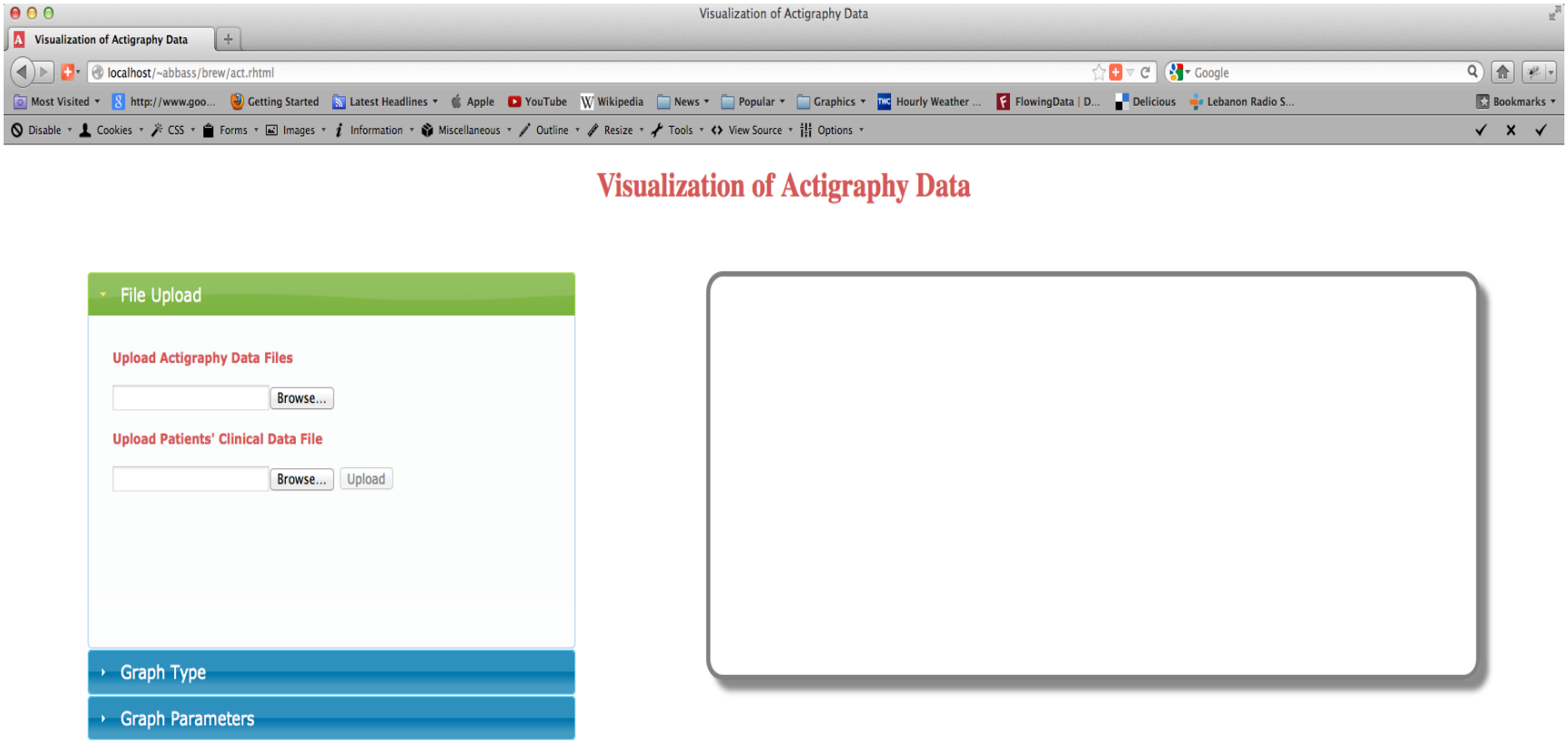
Case Study: Raw Data Plot



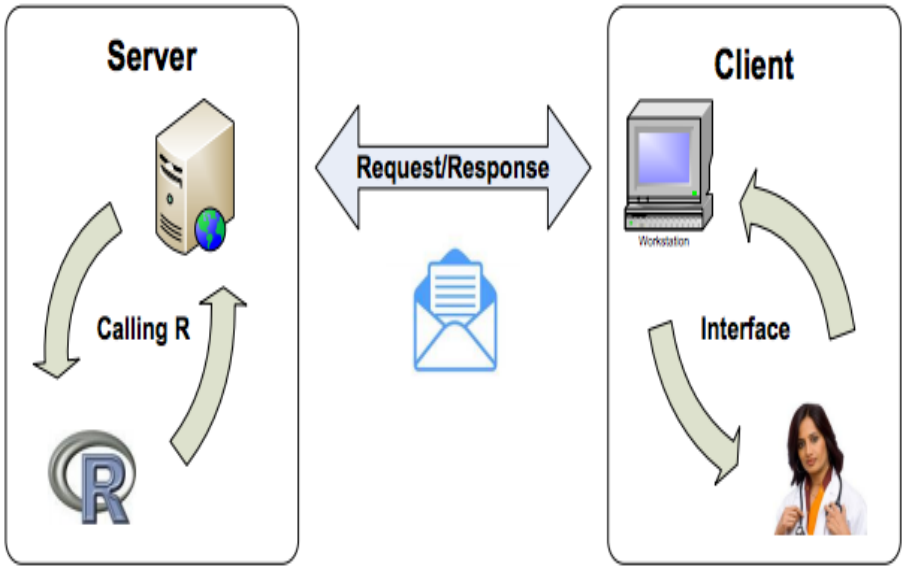
Feature 3: User–friendly Web Interface

- Main users of the R package are doctors in the medical field
- Easy–to–use interfaces are needed (users unlikely to learn R)
- Approaches:
  - Windows interface
  - Web interface (everyone knows how to operate a web browser)
    - Rpad approach
    - Rook approach
    - rApache approach

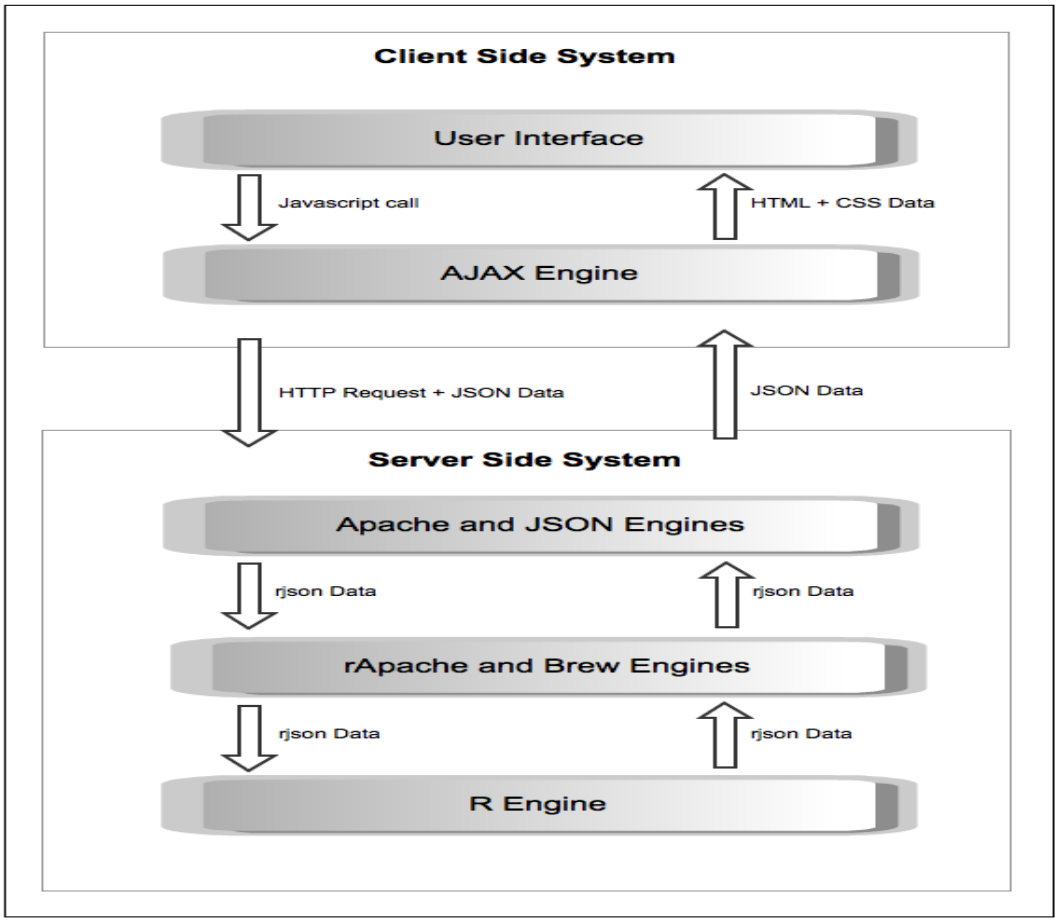
ActiVis Web Interface



Client–Server Architecture (1)



ActiVis Client–Server Architecture (2)



Summary

- Development of ActiVis R package (Prototype), including
  - New visualization tools for actigraphy data
  - OO–design
  - Web–based user interface
- Tested on single data set (55 patients) and on simulated data set

Future Work

- Finalize R package (and documentation) and submit to CRAN
- Test with additional data sets
- It's OO: Extend to different types of actigraphy & functional data!
- Extend graphics, e.g., support dendograms in multivariate time series plots
- More interactivity in the web interface (zooming in/out, more plot parameters, etc.)

Further Reading

Interface, 2010

Sharif, A., Symanzik, J. and Shannon, W. D. (2010), An Object–Oriented Approach in R for the Visualization of Functional Actigraphy Data, Computing Science and Statistics.

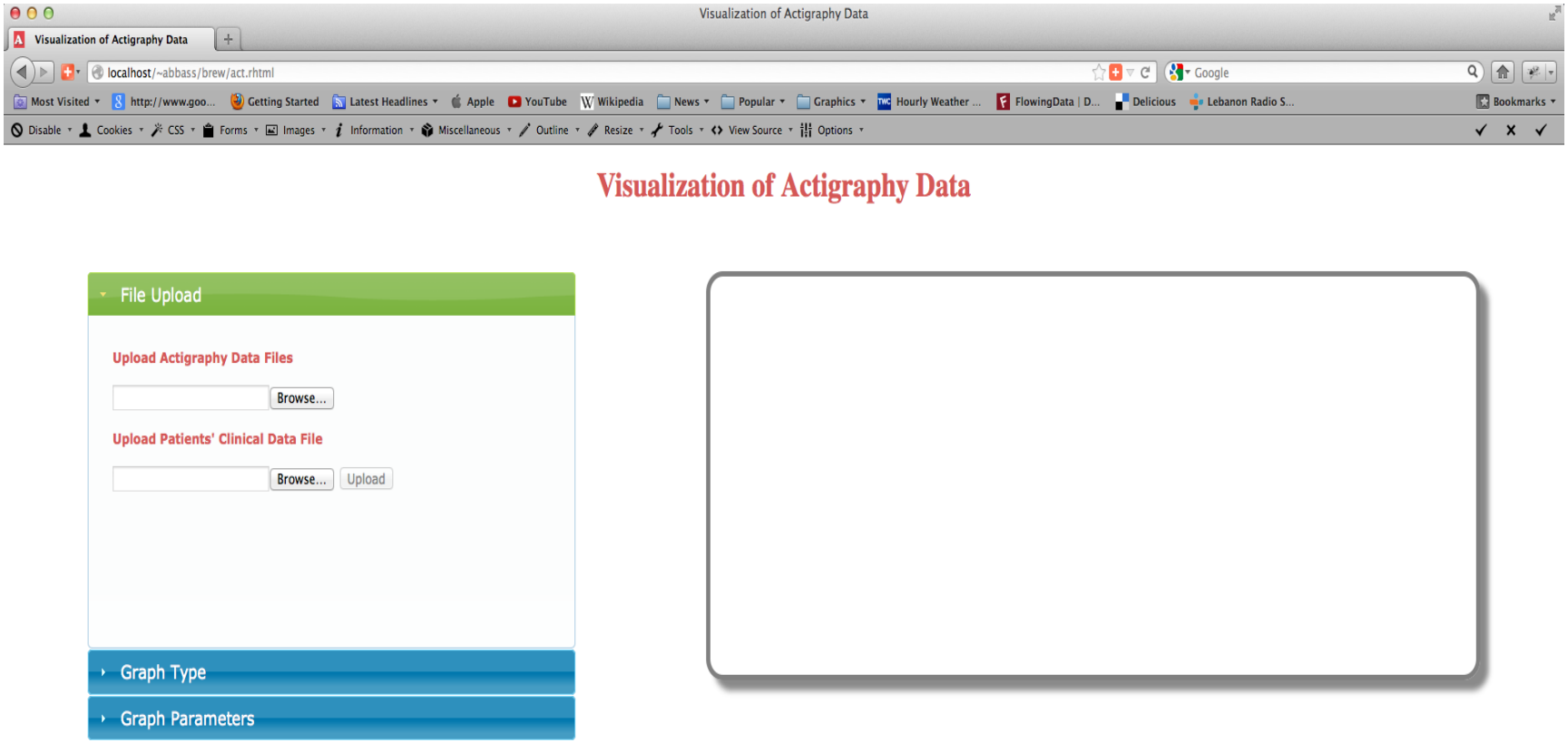
Chance, 2011

Ding, J., Symanzik, J., Sharif, A., Wang, J., Duntley, S. and Shannon, W. D. (2011), Powerful Actigraphy Data Through Functional Representation, Chance 24(1), 30–36.

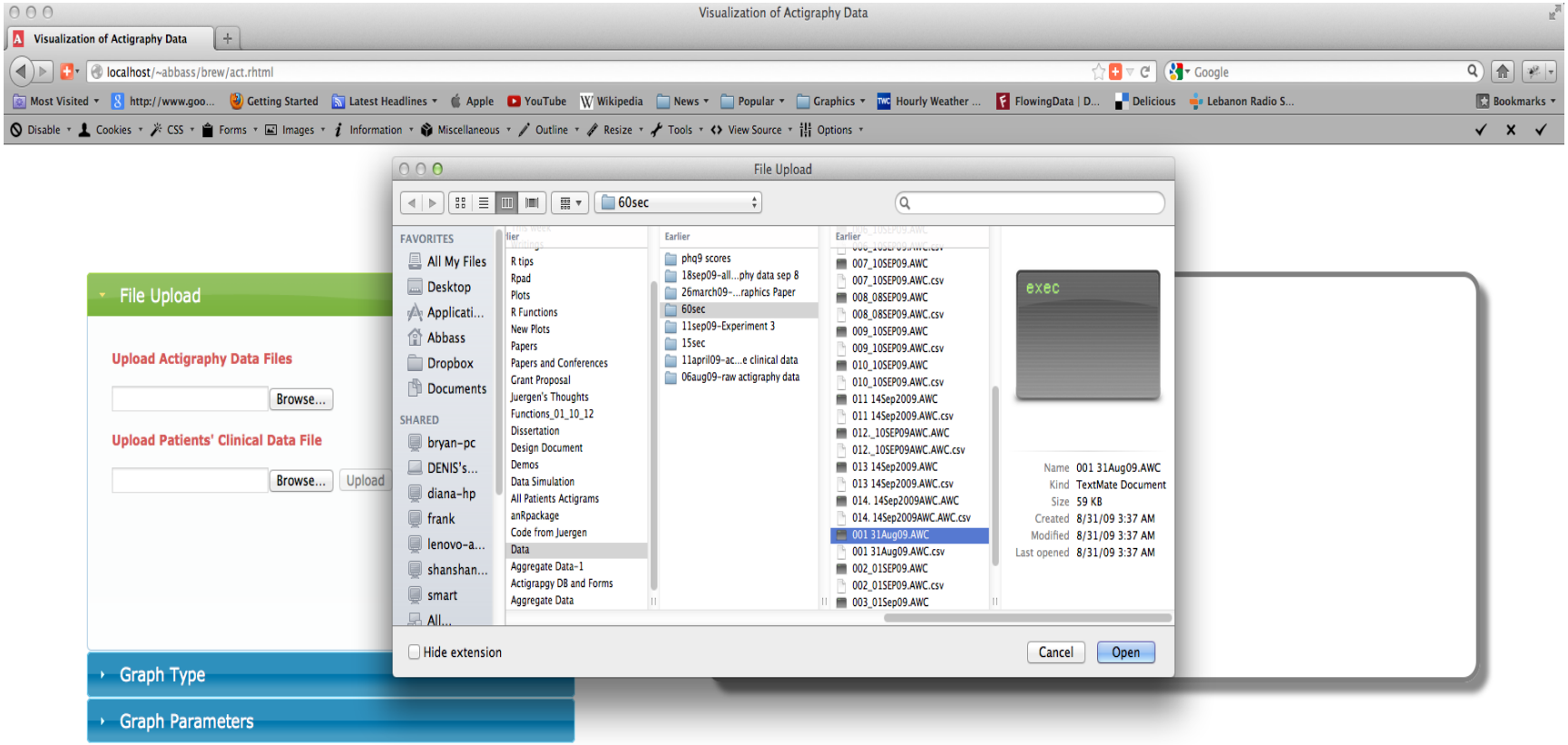
JSM, 2012

Sharif, A. and Symanzik, J. (2012), Graphical Representation of Clustered Functional Actigraphy Data, in 2012 JSM Proceedings, American Statistical Association, Alexandria, VA.

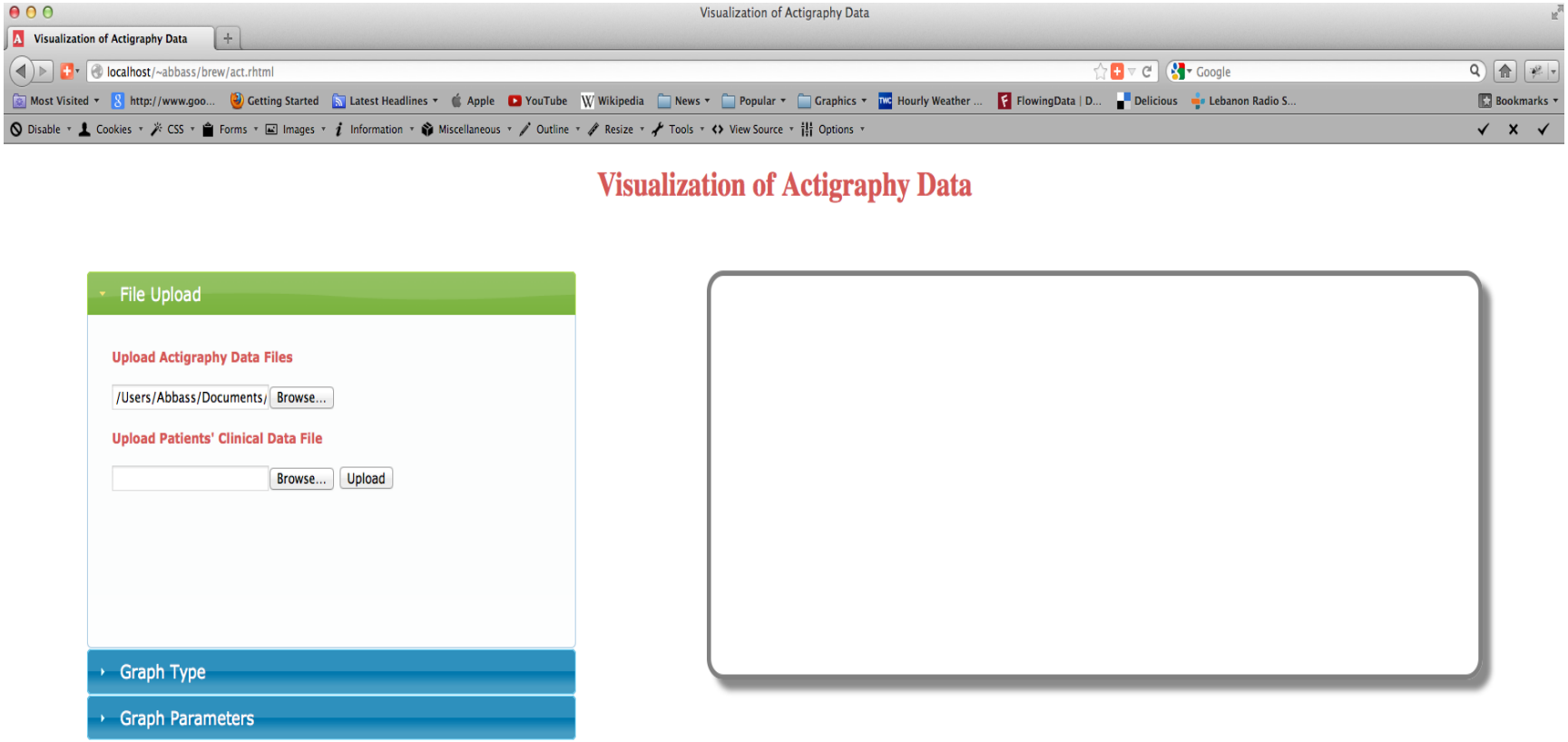
Web Interface: Main Page



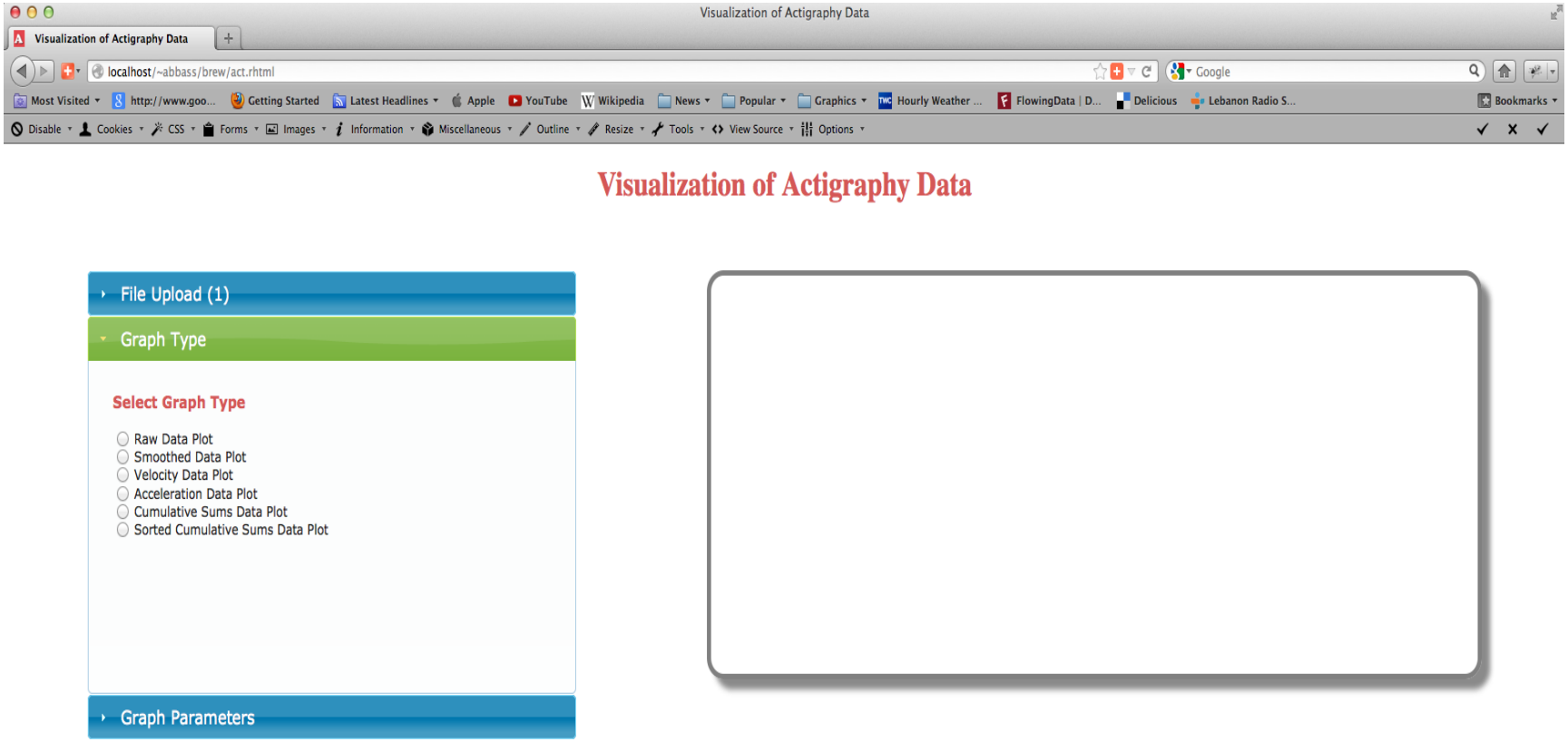
Web Interface: Upload Files



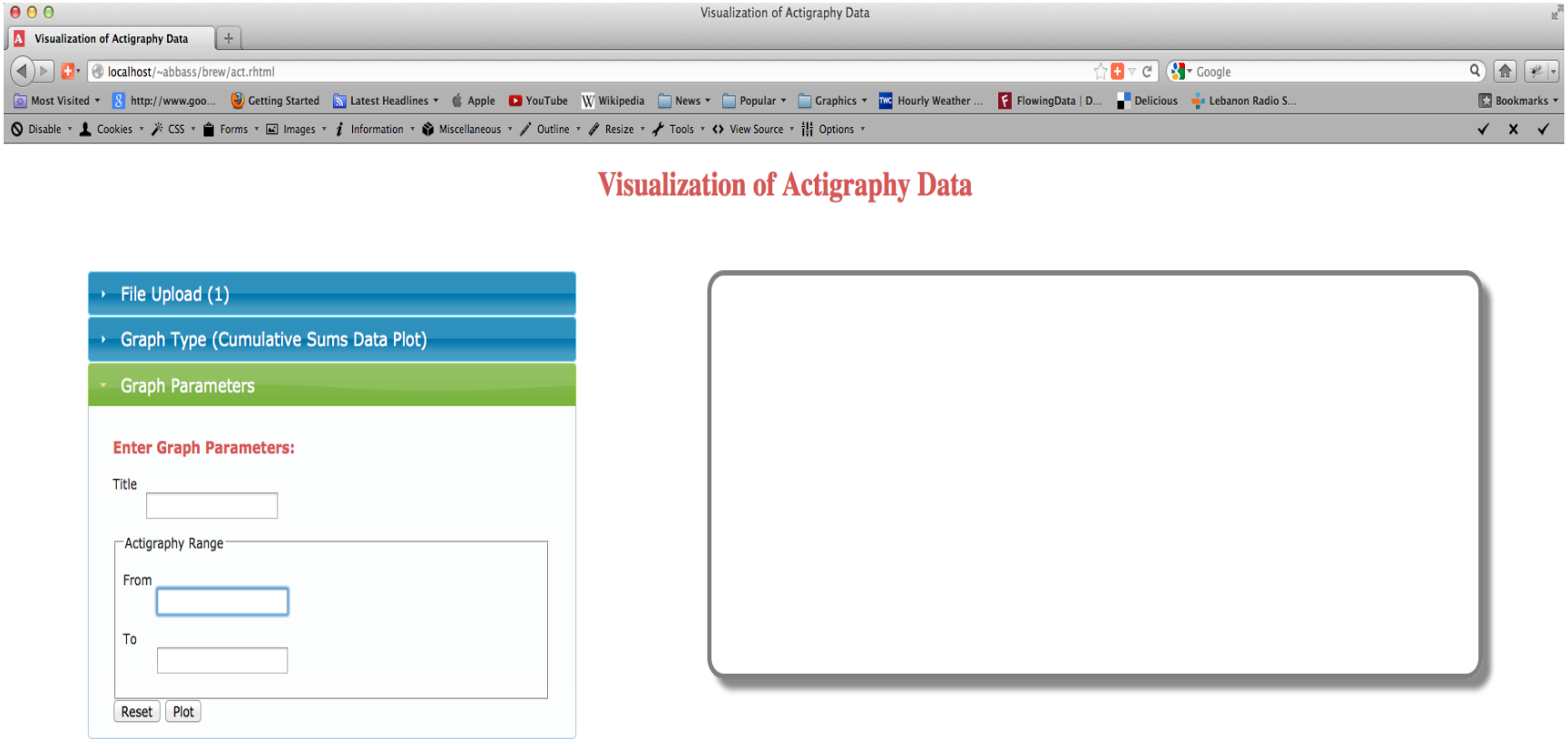
Web Interface: Files Selected



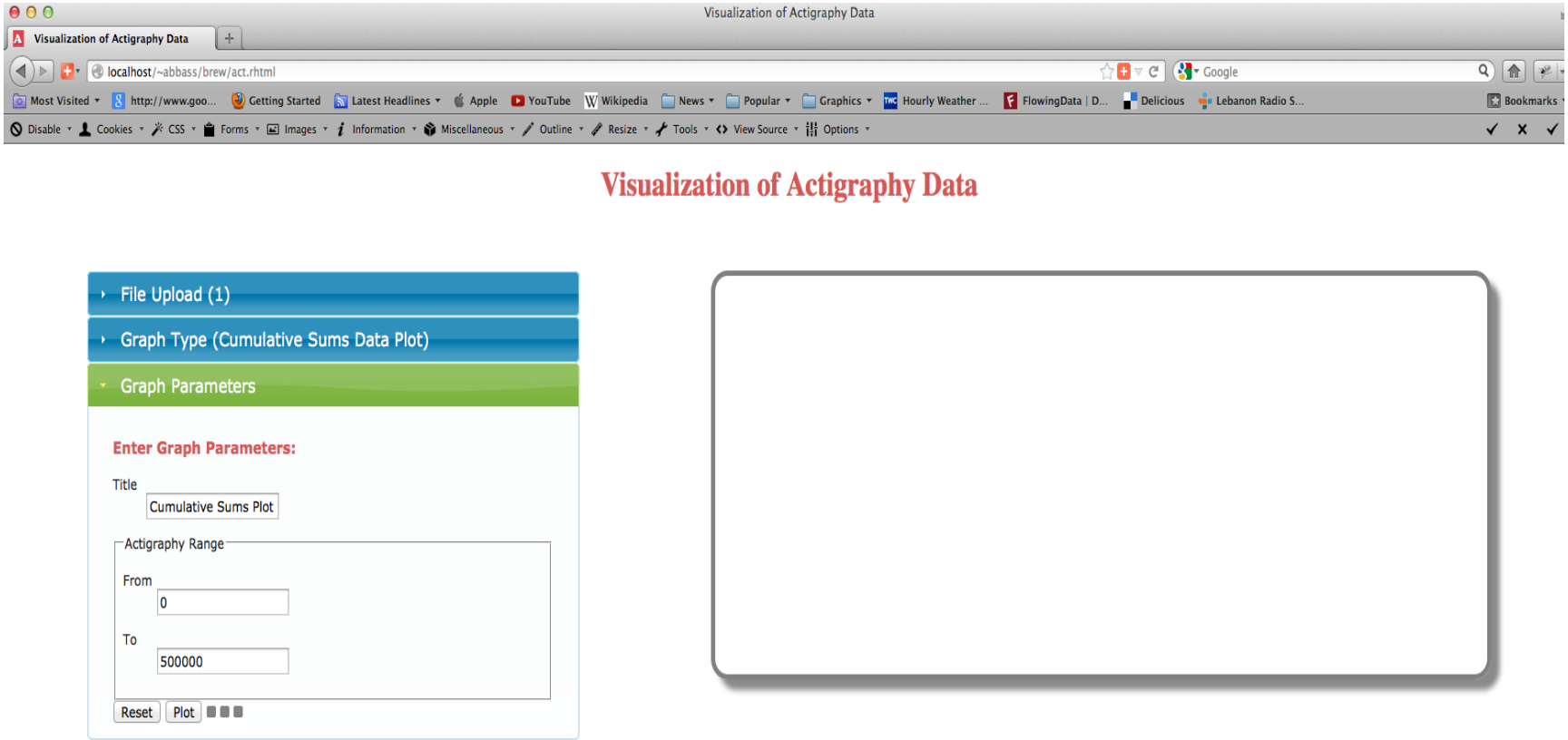
Web Interface: Choose Plot Type



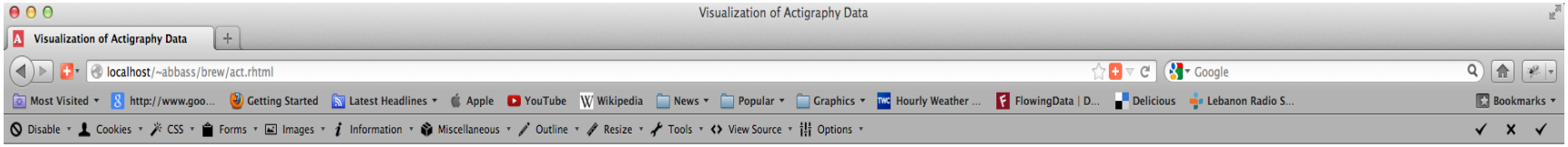
Web Interface: Enter some Parameters



Web Interface: Plotting



Web Interface: The Plot



Visualization of Actigraphy Data

File Upload (1)

Graph Type (Cumulative Sums Data Plot)

Graph Parameters

Enter Graph Parameters:

Title

Cumulative Sums Plot

Actigraphy Range

From

0

To

500000

Reset Plot